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Colonization of the Krakatau Islands (Indonesia) by Scorpions

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Max Vachon1)・安部琢哉2)：クラカタウ諸島（インドネシア）への サソリの侵入

Abstract: The Krakatau Islands, located between Java and Sumatra, consist of 4 islands which were sterilized by the volcanic eruption of Krakatau in 1883. 1982, three species of scorpions were collected in the islands. Two of these species had been previously recorded from the islands; *Chaerilus variegatus nigricolor* in 1908 and 1933, and *Lychas mucronatus* in 1933, but the other species *Liocheles australasiae* was newly recorded, The number of species of scorpions in the Krakatau Islands has thus continued to increase slowly: 1 in 1908, 2 in 1933 and 3 in 1982.

Islands sterilized by volcanic eruption have provided biologists with an opportunity to perform "natural experiments" for studying the process of colonization. The best-known biological recolonization is that on Krakatau (now called Rakata Besar), which erupted in 1833. During the first 50 years following the eruption, many studies were conducted on the fauna and flora of the island (Dammerman, 1948; Docters van Leeuwen, 1936) and two species of scorpions had been recorded from the Krakatau Islands by 1933. However,few intensive faunal studies have been subsequently conducted.

In 1982, T. Abe conducted an intensive survey of soil animals on the Krakatau Islands and collected 3 species of scorpions, which were identified by M. Vachon. The presest paper describes the scorpion fauna of the Krakatau Islands and adjacent areas and also discusses possible routes of colonization of this island group.

Study Areas and Methods

The Krakatau Islands are located about 60 km from Java and 40km from Sumatra,

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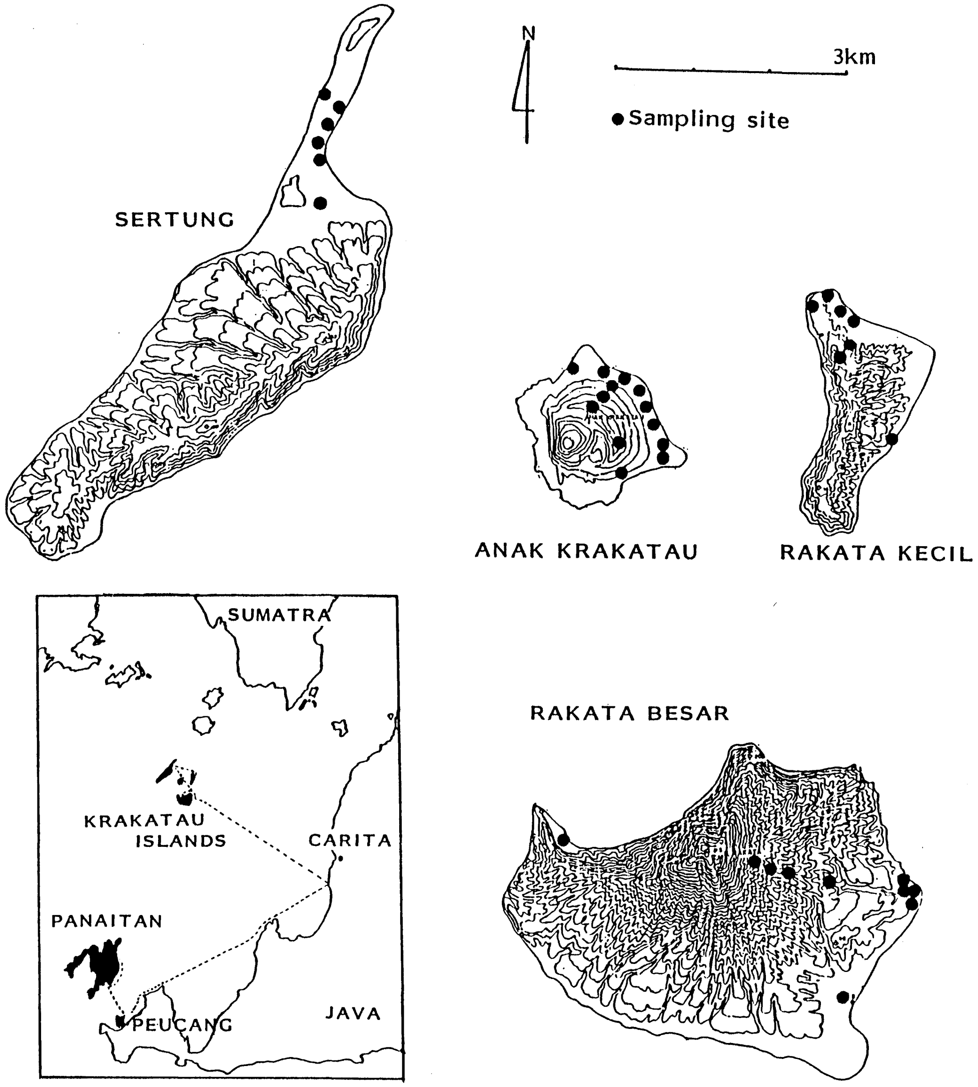

Fig. 1 The map of the Krakataku Islands showing the sampling sites of scorpions.

and consist of 4 small closely-situated islands: Rakata Besar (=Krakatau), Rakata Kecil (= Lang), Sertung (=Verlaten) and Anak Krakatau (Fig.1). The 1883 eruption of Krakatau destroyed more than half of the island and left the remaining Krakatau and the neighbouring islands of Sertung and Rakata Kecil buried under 30-60m of hot ash and pumice. The entire flora and fauna of these islands are believed to have been almost completely destroyed at that time. In 1930, a new volcanic island, Anak Krakatau, was born in the centre of the three islands of Krakatau. The island was rapidly colonized, but the vegetation was almost totally destroyed again by eruption in 1952 (Waalkes, 1960), and therefore was actually 30 years old in 1982.

Scorpions were sampled in the Krakatau Islands, Panaitan Island (located about 15 km off Ujung Kulon on the west tip of Java), Peucang Island (a small island near Ujung Kulon) and Carita (a small village in the west coast of Java). Sampling sites are shown in Fig.1. The recent vegetation of the Krakatau Islands has been described by TAGAWA *et al.* (1985) and WHITTAKER *et al.* (1984). The inland areas of Rakata Besar, Rakata Kecil and Sertung were covered with dense mixed forest, while Anak Krakatau was mainly barren due to continuous volcanic activity. Panaitan Island was not seriously disturbed by the explosion of Krakatau and was covered with evergreen and deciduous trees. Peucang Island was covered with forest growing on limestone. At Carita, scorpions were examined at the coastal area and at the *Shorea* experimental forest situated further inland.

At each sampling plot, soil samples (1m x 1m, 10 cm in depth) and at least 10 cut pieces of fallen wood were examined for the presence of scorpions, any scorpions present were collected and preserved in 70% alcohol for taxonomic investigation. The wood examined was classified into 3 groups and 5 ranks; hard and usually dry wood (ranks 1 and 2), soft and generally wet wood (ranks 3 and 4), and fragile wood (rank 5).

The present survey was carried out from October 18 to November 14,1982, and the period of intensive study on each island was as follows: 4 days in Panaitan, 0.5 day in Peucang, 2 days in Carita, 5 days in Rakata Besar, 4.5 days in Anak Krakatau, 2.5 days in Rakata Kecil and 3 days in Sertung.

Result

1. Scorpions Collected from the Krakatau Islands and Their Adjacent Areas[3]

The following species were collected from the Krakatau Islands and their adjacent areas from October to November, 1982. The names of the islands or villages are subsequently abbreviated as follows : RB (Rakata Besar), SE (Sertung),RK (Rakata Kecil), AK (Anak Krakatau), CA (Carita), PE (Peucang) and PA (Panaitan).

The four species collected in the present study belong to four genera and four different families : *Chaerilus variegatus nigricolor* (Chaerilidae),*Lychas mucronatus* (Buthidae), *Liocheles australasiae* (Ischnuridae) and *Heterometrus cyaneus* (Scorpionidae).

These four species are easily recognizable. *H. cyaneus*, which does not occur in the Krakatau Islands, is a large species, dark-coloured, the size of which can reach, in the adult, 9-10 cm including the tail, the 3 other species being smaller than 6 cm when adult.

Liocheles australasiae, the smallest species (less than 3 cm) is recognizable by its short tail, which is markedly shorter than its body (about one half) and by the yellow colour of its vesicle.

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3) The specimens deposited in the Museum Zoologicum Bogorense

In *Lychas mucronatus*, the body and the walking legs are spotted with black on a yellowish back ground. The chela ending the pedipalps with fingers are slender; the hand is cylindrical and the fingers are twice as long as the hand.

In *Chaerilus variegatus nigricolor*, a species with body and legs uniformly dark-coloured, the chelae are thick; the hand is as large as it is wide and the fingers are shorter than the height of the hand. Other characters, specific to each of the four species, will be given in detail in the following list.

Family Chaerilidae

(1) *Chaerilus variegatus* SIMON, 1877 *nigricolor* POCOCK, 1899.

6♂, 9♀, RB, 27~31-x; 1, CA, 16-xi; 1♀, PE, 17-x; 4♀, PA, 19-x.

Species reaches 4 to 5 cm in the adult, dark brown coloured (body,walking legs, tail and vesicle); tail as long as body proper. Chela ending the pedipalps with fingers shorter than the hand; the hand is as long as it is high with its internal edge posteriorly lobate; anterior margin of the body rectilinear;ventral pectines with only 5 to 8 teeth.

This species was first described from Java. According to KRAEPELIN (1913, p.143), its presence in Borneo is questionable and it has not been recorded from Sumatra. KRAEPELIN (1899, p.158) admitted the synonymy of *Ch. variegatus* and *Ch. borneensis*. An examination of the type specimens of these two species, deposited in Museum of Paris, showed *Chaerilus borneensis* SIMON, 1880 to be a valid species, differing from *Chaerilus variegatus* SIMON, 1877, and it may be stated that *Ch. variegatus* is endemic to Java.

The presence of this scorpion on Rakata Besar was already noted by DAMMERMAN (1948) on the basis of data provided by JACOBSON (1909) and KOPFSTEIN (1935).

Family Buthidae

(2) *Lychas mucronatus* (FABRICIUS, 1798).

1♂, 1♀, RK, 10-xi.

Species size reaching 5 cm in the adult; its tail is longer than the body; brownish yellow colouration with blackish patterns on the body and on the walking legs; last rings of the tail darker than the others; vesicle, at the base of the string, with a small triangular tooth peculiar to the genus *Lychas*; the chela ending the pedipalp is narrow ; the hand is almost cylindrical, straw coloured, whereas the fingers are dark-brown; the tibia is basically light; the remaining part of the structure being darker, anterior margin of the body slightly concave; ventral pectines with more than 20 teeth. The presence of this species on Rakata Besar had already been noted by KOPFSTEIN (1935).

The genus *Lychas* is widely distributed: India, Burma, Malaya, Philippines, Thailand, China, Australia, East, West and South Africa (TIKADER & BASTAWADE, 1983, p. 410). Its revision was given by VACHON (1985, 1986). The species *mucronatus* is known from Thailand, China, Hainan Island, Sunda Isles, Japan and Philippines(?).

Family Ischnuridae

(3) *Liocheles australasiae* (FABRICIUS, 1775)
5♀, SE, 12~13-xi; 2♀, CA, 2-xi; 3♀, 11 im, PA, 19~22-x.

This small species does not reach 3cm. It is easily recognizable through the smallness of its tail: tail half as long as the body; tergites smooth; fingers of the chela ending the pedipalps, clearly shorter than the hand; dorsal side of the hand flat; frontal margin nearly straight, slightly V-shaped; ventral pectines with only 4 to 7 teeth.

This species was for a long time classified in the genus *Hormurus* THORELL, 1876. KOCH (1977) placed it in the genus *Liocheles* SUNDEVALL, 1893, subfamily Ischnurinae and FRANCKE (1985) later raised the subfamily to the family level: Ischnuridae Simon, 1879.

This scorpion is widely distributed, inhabiting most Pacific Islands: Sunda Islands, Micronesia, Polynesia, Australia, and so on. It has also been recorded from the Asiatic continent: the Himalayas(?), China, Korea, Thailand and South Vietnam (KOCH, 1977). This species was newly recorded from the Krakatau Islands.

Family Scorpionidae

(4) *Heterometrus* (*Javanimetrus* COUZIJN, 1981) *cyaneus* (KOCH, 1836).
2♂, 1♀, 1 im., PA 19-x.

The genus *Heterometrus* is widely spread over the tropical region of the Asiatic continent and Indonesia. The genus was revised in 1981 by H. W. COUZIJN who recognized 24 species and divided it into 5 subgenera (two of which were new).

The species from Panaitan Island (Fig. 1) does not occur in the Krakatau Islands, but is widely spread in Java and northern Borneo. It is a large species; the adult can exceed 9 to 10 cm in length; the general colour of the body and appendages is bright black; the integuments show carinae and granulations; the anterior margin of the body is deeply V-shaped. The fingers of the chela are larger than the hand, the internal edge of which is posteriorly locate; the ventral pectines, ♂or♀, show 12-13 teeth.

2. Sex Ratio of Scorpions

Except those species where secondary sexual characters occur, the sex of scorpions is very difficult to distinguish. Unfortunately this proved the case for the species collected in the Krakatau Islands.

Liocheles australasiae: According to the data given by KOCH (1977, p.163), the number of pectinal teeth varies from 4 to 8 in the females and from 8 to 9 in the males. The 5 specimens from Sertung all show 6 or 7 pectinal teeth and are therefore considered as being females. The specimens from the neighbouring localities such as Panaitan and Carita also show 6 or 7 pectinal teeth and therefore all 10 specimens of *L. australasiae* collected are females. This lack of males corroborates the conclusion by Makioka & Koike (1984, 1985) that this species is parthenogenetic. Pelt (1936), studying the scorpions from Beru Island, located in the Seram Sea between the islands of Celebes and New-Guinea, reviewed 261 specimens of *Liocheles* (=*Hormurus*) *australasiae*, among which only five males were present, i. e. under 2 % of the samples were male.

Chaerilus variegatus nigricolor: the sexual distinction of this species is as difficult as in the preceding species. Kraepelin (1913, p.147) describes the females of *Ch. variegatus* as having 3 to 5 pectinal teeth whereas the males have 5 to 7. The 15 specimens from Rakata Besar were found to consist of 6 males and 9 females.

Lychas mucronatus: The sexual distinction is simplified by examination of the arrangement of the pectines, which, in the males, are overlapping at their bases, whereas they are distinct from one another in the females (Farzenpay & Vachon, 1979). The number of teeth is not a sex specific character since males and females show approximately the same number of pectinal teeth. Due to the small number of specimens collected (only 2), no conclusion can be drawn concerning the sex ratio (1 male and 1 female). Kopfstein (1935) also recorded only two specimens (1 male and 1 female), collected by Dammerman from Rakata Kecil in April 1933.

3. Habitat of Scorpions

Although many sizes of fallen branch were examined, scorpions were collected only from large logs. The condition of the wood in which scorpions were found is shown in Table 1 along with information on the termites (probably an important food of scorpions) and other dominant animals present in the wood. Most scorpions were found in soft and generally wet wood (rank 3 and 4). Between one and three scorpions were found in a log. Of 16 logs containing scorpions, 11 were found to contain many termites. The termite fauna in the Krakatau Islands has been reported by Abe (1984).

In Rakata Besar, fallen logs were examined up to 500m alt., and *Ch. variegatus nigricolor* was found at up to 240m. The species was rather commom and widely distributed in Rakata Besar.

Discussion

The temporal change in the scorpion fauna of the Krakatau Islands is summarized in Table 2, along with the worldwide distribution of these scorpions. The total number of scorpion species present continued to increase slowly; 1 species in 1908, 2 species in 1933 and 3 species in 1982. As stated above, each island of the Krakatau Islands was inhabited

Table 1 Wood conditions containing scorpions.

		Wood conditions			Animals in the wood		
Wood No.	Locality	Length (cm)	Diameter (cm)	Rank of hardness	No. of scorpions	Termites	Other dominant animals
1	RB	200	16	2	Cvn1	−	Coloeoptera (larvae)
2	RB	250	42	4	Cvn3	+ (Pr)	Thelyphonida, ants
3	RB	200	22	4	Cvn1	−	Thelyphonida, ants Diplopoda, Blattoidea
4	RB	100	13	4	Cvn3	−	Diplopoda, ants
5	RB			4	Cvn1	+ (Pr)	Thelyphonida, ants Coleoptera (larvae)
6	RB	250	11	4	Cvn1	+ (Sj)	Ants, Oligochaeta, Blaattoidea, Chilopoda
7	RB	300	14	3-4	Cvn1	−	Thelyphonida, ants
8	RB	100	25	4	Cvn1	+ (Sj)	Thelyphonida
9	RB		40	3-4	Cvn1	+ (Pr)	Coleptera (llarvae)
10	RB	150	25	4	Cvn1	+ (Nm)	Opiliones
11	RB	300	35	3-4	Cvn2	+ (Nm, Pr, Sj)	Coleoptera (larvae), ants
12	RK	200	28	3-4	Lym1	+ (Pr)	Diplopoda
13	SE	20	28	2-5	Lia1	+ (Cd)	Coleoptera (adults), ants
14	SE	100	18	3	Lia2	−	−
15	SE	400	39	3-4	Lia1	+ (Nm,Pr)	Coleoptera (larve)
16	SE	300	20	4	Lia1	+ (Sj)	−

Abbreviations are as follows: Locality; RB :Rakata Besar, RK: Rakata Kecil, SE: Sertung, Scorpions; Cvn: *Chaerilus variegatus nigricolor,* Lym: *Lychas mucronatus*, Lia: *Liocheles australasiae*, Termites; Pr: *Prorhinotermes* sp., Sj: *Schedorhinotermes javanicus*, Nm: *Nasutitermes matangensis*, Cd:*Cryptotermes domesticus*

Table 2 Temporal change of scorpion fauna in the Krakatau Islands.
Abbreviations are as follows; RB: Rakata Besar; RK: Rakata Kecil; SE:Sertung.

Species	1908 1)	1933 1)	1982 2)	No.of samples in 1982	Distribution
Chaerilus variegatus nigricolor	RB	RB	RB	15	Java 3) 4)
Lychas mucronatus	−	RK	RK	2	Java, Sumatra, Malaya, SE Asia 4)
Liocheles australasiae	−	−	SE	5	Java, Sumatra, SE Asia, Melanesia, Australia, etc 5)
Total number of species	1	2	3		

1) Jacobson (1909), Kopfstein (1935)., Dammermann (1948) 2) Present paper
3) Pocock (1899) 4) Kraepelin (1913) 5) Koch (1977)

by only one species. It seems reasonable to assume that all scorpions, as well as other animals present in the Krakatau Islands, were exterminated in 1883 when Krakatau erupted violently. Therefore, the scorpions found must have reached the Krakatau Islands by rafting from adjacent areas such as Sumatra and Java. *Ch. variegatus nigricolor* has been described from Java (Pocock, 1899) but has not been recorded from Sumatra. This species on the Krakatau Islands seems to be of Javanese origin, although the insufficiency of faunal studies in Java and Sumatra makes it difficult to locate the source area with confidence. In 1982, this species was found in West Java (Carita) and its neighbouring islands (Panaitan and Peucang). This species seems to have been present on Rakata Besar for more than 70 years and was rather common there in 1982. It is difficult to explain why this species has not colonized other adjacent islands, such as Rakata Kecil and Sertung, in spite of having succeeded in reaching Rakata Besar from Java.

The source areas of *L. australasiae* and *Ly, mucronatus* cannot be accurately identified because they inhabit both Java and Sumatra.

As to the source areas, Dammerman (1948) considered the majority of Krakatau fauna to be of Sumatran origin, whereas Yukawa (1984) reported that with regard to butterflies, which must have reached the islands by flight, the Javanese element had preponderance over the Sumatran one. A similar but less marked tendency was reported for aculeate wasps (Yamane, 1983) which also must have reached the islands by flight.

However, Abe (1984) recognized a reverse trend in termites, which are believed to have reached the islands by rafting and thus the source areas of the various Krakataun fauna may differ according to the dispersal methods of the animal group.

Conclusions

Twenty two scorpions were collected from the Krakatau Islands. On each island, only one species was found: on Rakata Besar, *Chaerilus variegatus nigricolor* (Family Chaerilidae), a species first recorded there in 1909, and recorded there in 1935, 1948 and 1982; *Lychas mucronatus* (Family Buthidae) first collected from Rakata Kecil in 1935 and also found in 1982. *Liocheles australasiae* (Family Ischnuridae) was collected for the first time from Sertung in 1982. Despite intensive searches,no scorpions were found on Anak Krakatau Island in 1982.

The species *Chaerilus variegatus nigricolor* is believed to have colonized Rakata Besar from Java Island, whereas *Lychas mucronatus* on Rakata Kecil and *Liocheles australasiae* on Sertung could have originated from Java as well as from Sumatra, these two species being widely spread in Indonesia.

Conclusions

Vingt-deux Scorpions ont été collectés en 1982 dans l' archipel des Krakatau par mission ABE. Chaque île n'est habitée que par une seule espèce: *Chaerilus variegatus nigricolor* (Fam. Chaerilidae) dans l'île Rakata Besar, espèce déjà présente en 1909, puis retrouvée en 1909, puis retrouvée en 1935, en 1948 et en 1982; *Lychas mucronatus* (Fam. Buthidae) était déjà présente en 1935 dans l'île Rakata Kecil, elle a été retrouvée en 1982. L'espèce *Liocheles australasiae* (Fam. Ischnuridae) a été découverte pour la première fois dans l'île Sertung en 1982. Malgré d'intensives recherches, en 1982, dans l'île Anak Krakatau, aucun Scorpion n'a été trouvé.

La colonisation de Rakata Besar par l'espèce *Chaerilus variegatus nigricolor* s'est faite à partir de l'île de Java alors que *Lychas mucronatus* de Rakata Kecil et *Liocheles australasiae* de Sertung ont pu provenir, aussi bien de Java que de Sumatra, ces deux espèces étant largement répandue en Indonésie. Les données fournies par l'étude d'autres espèces animalux habitant actuellement l'archipel des Krakatau conduisent à la conclusion que la faune colonisatrice a des origines différentes dues aux possibilités écologiques variées des espèces animalux habitant les îles voisines de l'archipel des Krakatau.

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摘　要

インドネシアのクラカタウ諸島の生物は，1883年の火山の大爆発により，ほとんど全滅した。その後，この諸島に周辺地域から，多数の生物が侵入に成功し，現在ではそこに森林が形成されている。1982年，この諸島においてサソリの分布に関する調査を行った結果，*Chaerilus variegatus nigricolor, Lychas mucronatus, Liocheles australasiae*の３種が見出された。このうち*L. australariae*はクラカタウ諸島新記録である。クラカタウ諸島のサソリの種数は，1908年には１種，1933年には2種，1982年には３種とゆっくりではあるが増え続けている。

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